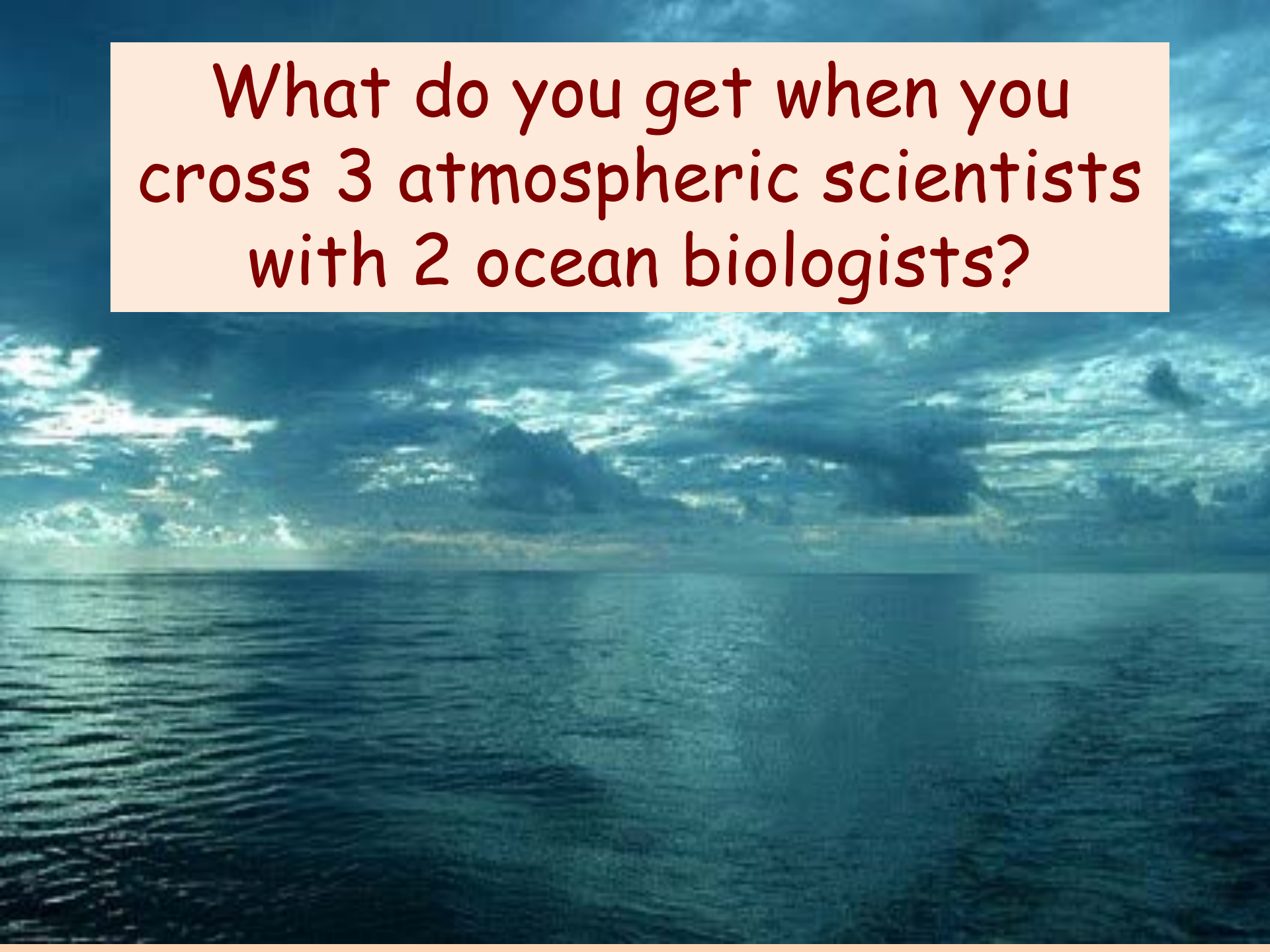
What do you get when you cross 3 atmospheric scientists with 2 ocean biologists?

Understanding airborne fertilization of oceanic ecosystems using MODIS, VIIRS and CALIPSO

Lorraine Remer, Yingxi Shi, Hongbin Yu
(the atmospheric scientists)

Toby Westberry and Michael Behrenfeld
(the ocean biologists)

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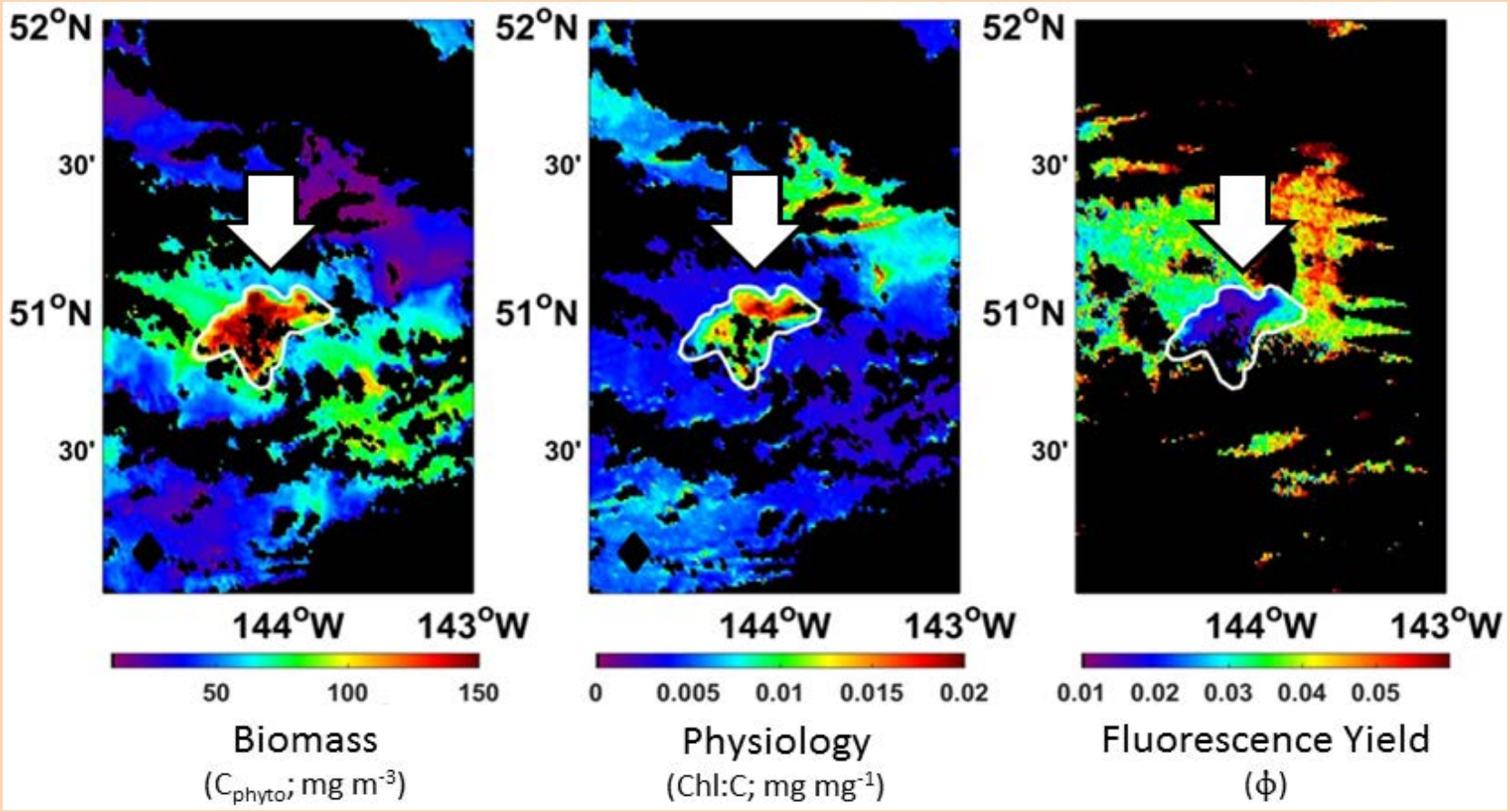
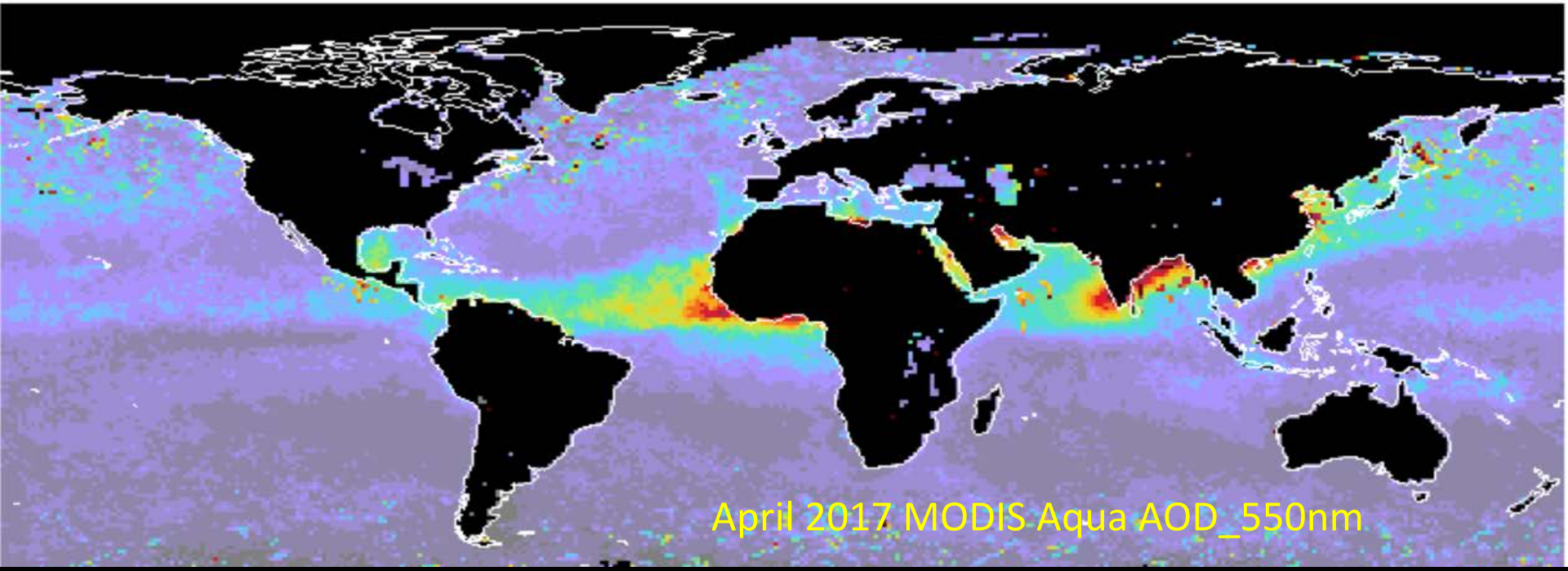
1983 - M.S. -Oceanography, Univ. of California San Diego
1991 - Ph.D.- Atmospheric Science, Univ. of California Davis

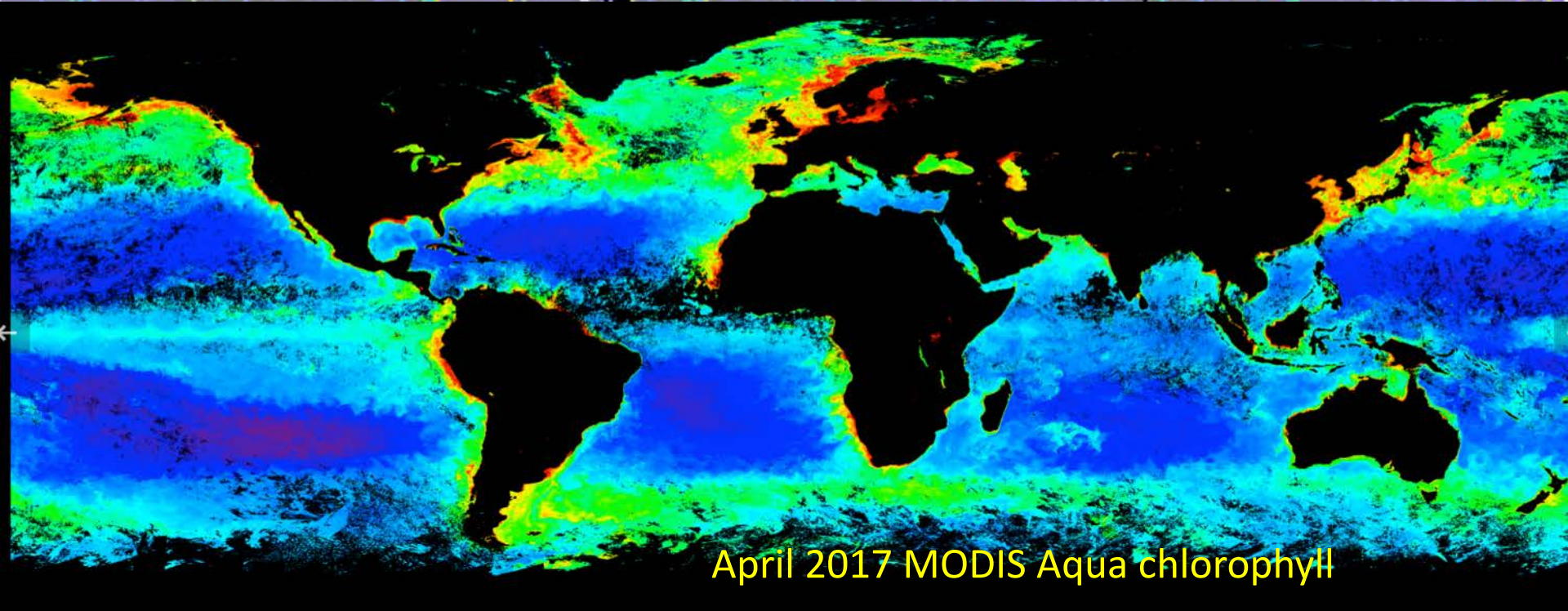
Artificially adding iron to ocean (a) increases biomass, (b) changes physiology and (c) cranks up carbon engine.

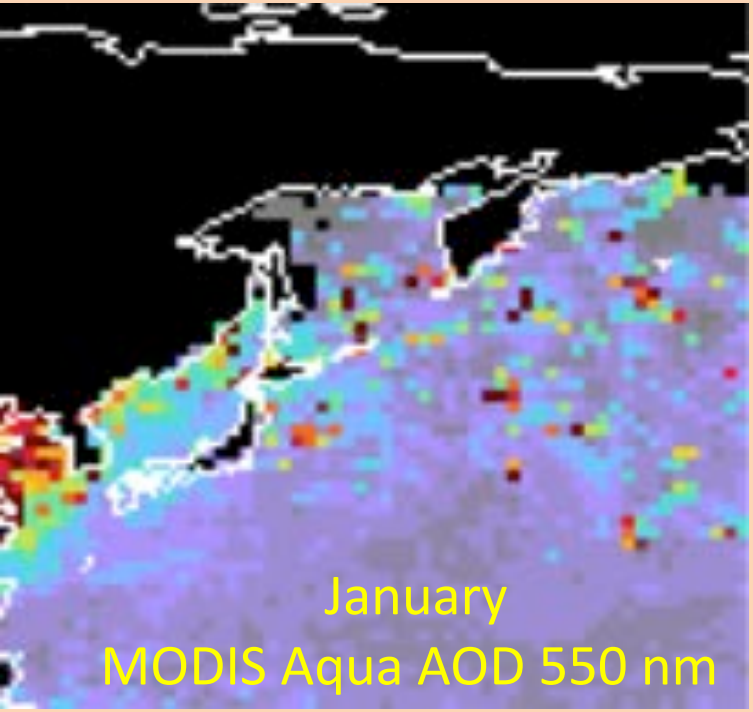
But… what about adding iron from aerosols?

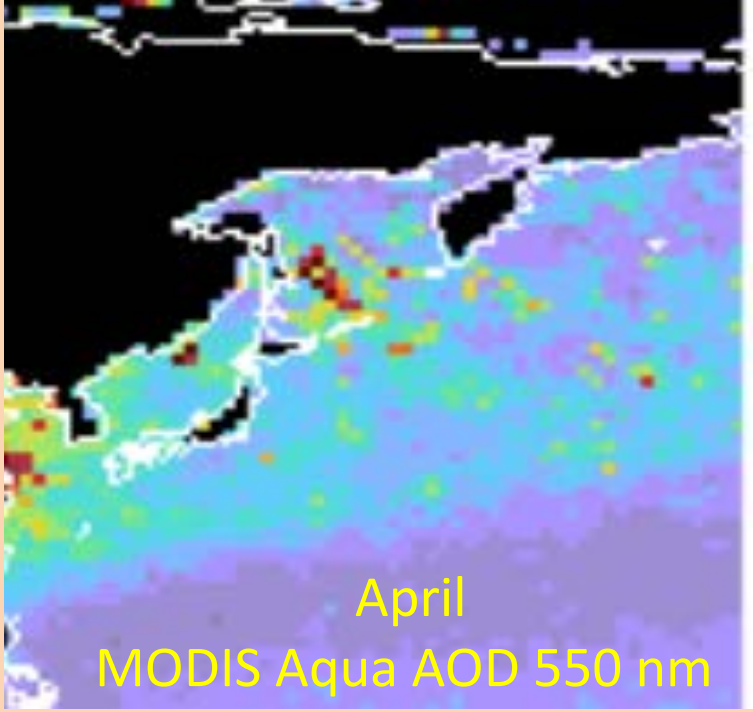


Westberry et al. (2013)

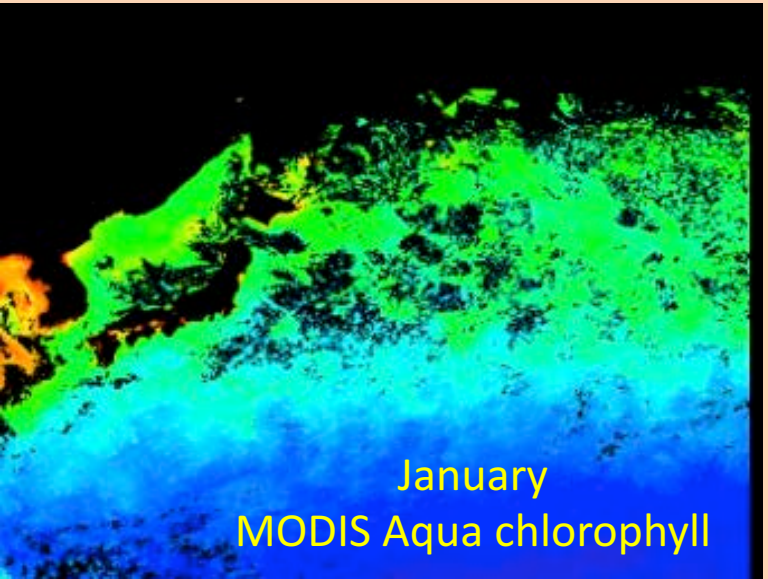

April 2017 MODIS Aqua AOD_550nm

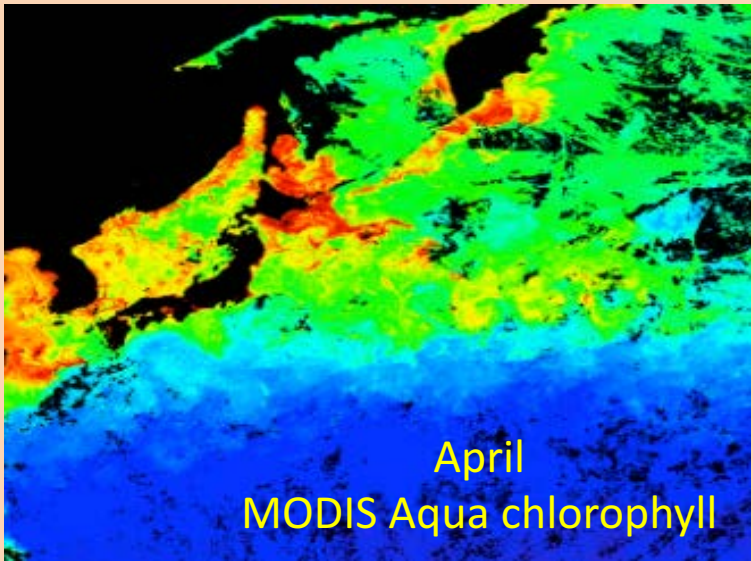

April 2017 MODIS Aqua chlorophyll


January
MODIS Aqua AOD 550 nm


April
MODIS Aqua AOD 550 nm

2017


January
MODIS Aqua chlorophyll


April
MODIS Aqua chlorophyll

Can you determine dust deposition from satellite?

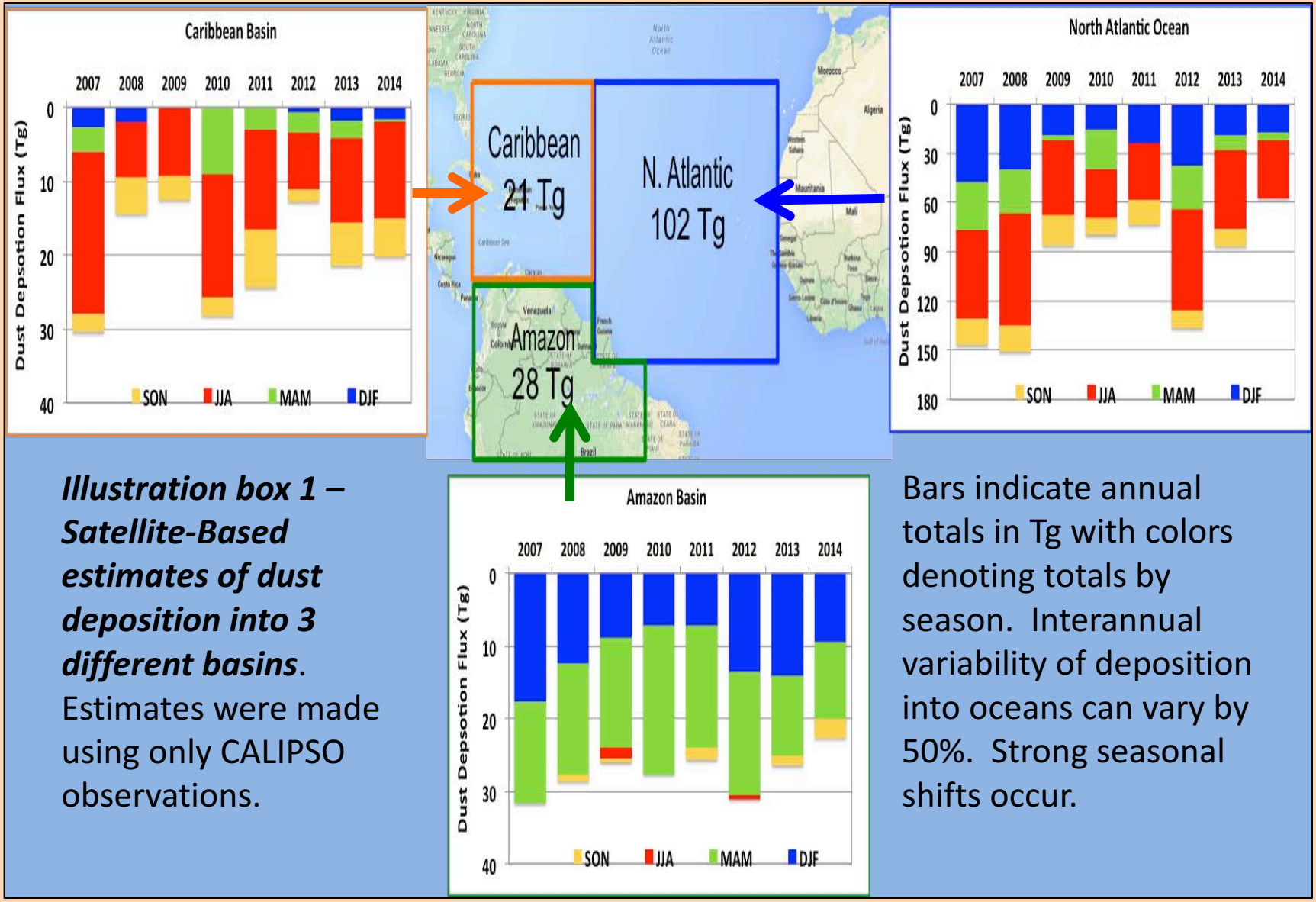
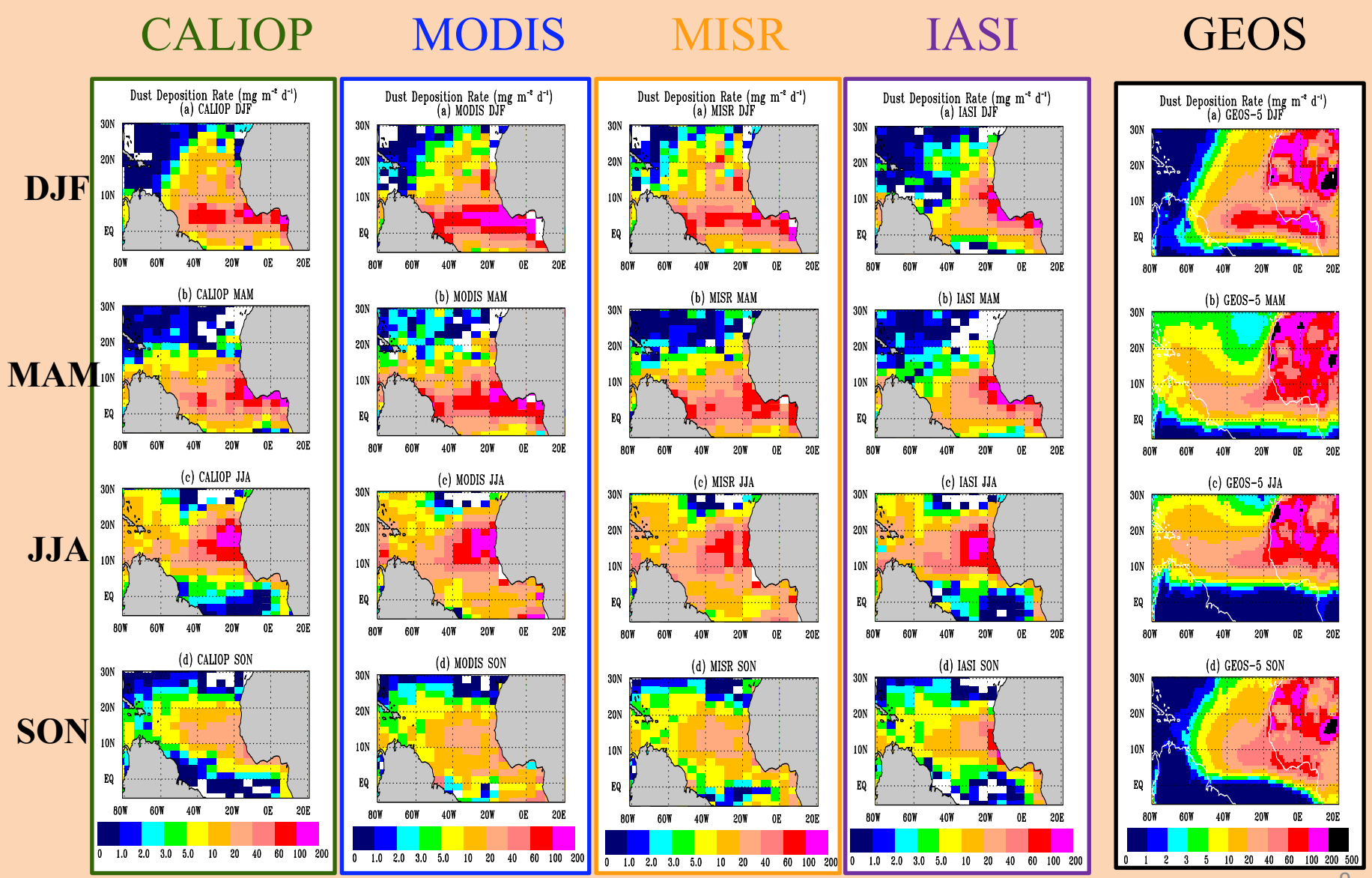


Illustration box 1 – Satellite-Based estimates of dust deposition into 3 different basins. Estimates were made using only CALIPSO observations.

Bars indicate annual totals in Tg with colors denoting totals by season. Interannual variability of deposition into oceans can vary by 50%. Strong seasonal shifts occur.

Hongbin Yu

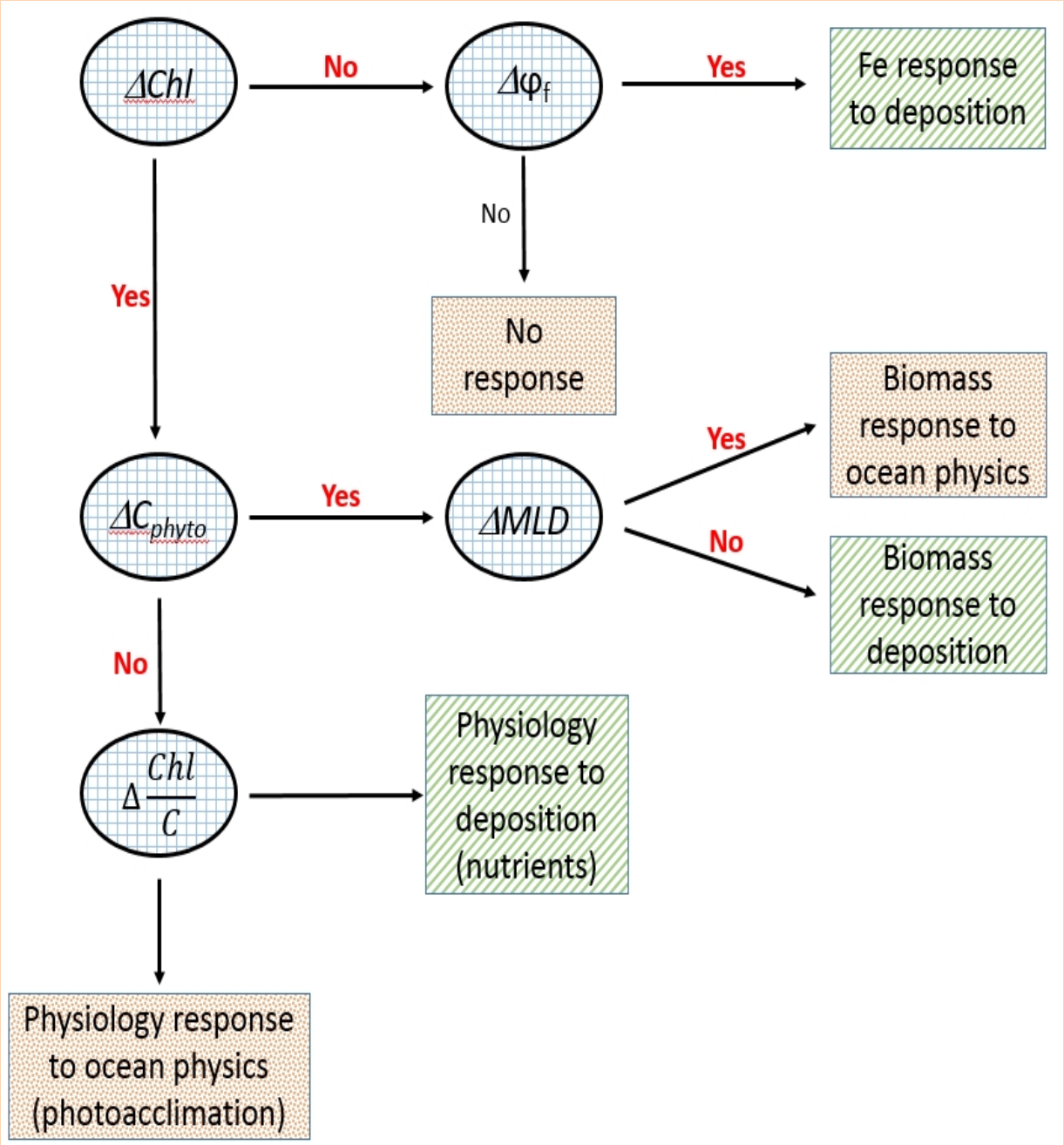
Dust Deposition: Satellites vs GEOS [2]



Hongbin Yu

On the ocean side:

There's a lot more than chlorophyll going on.



Proposed:

1. Create a data base of deposition events
2. Evaluate ecosystem responses to each event
3. Characterize aerosol and atmospheric conditions of events
4. Long-term statistics/synthesize of results

Panel response?

Panel response?

HA HA HA HA HA

Panel response?

HA HA HA HA HA

Caveats:

1. Clouds
2. Bio-availability of minerals
3. Upwelling and other sources of fertilization
4. You can't see the ocean properly through the dust
5. Grid size mismatch
6. Validity of deposition estimates (MERRA-2)
7. And more and more and more…

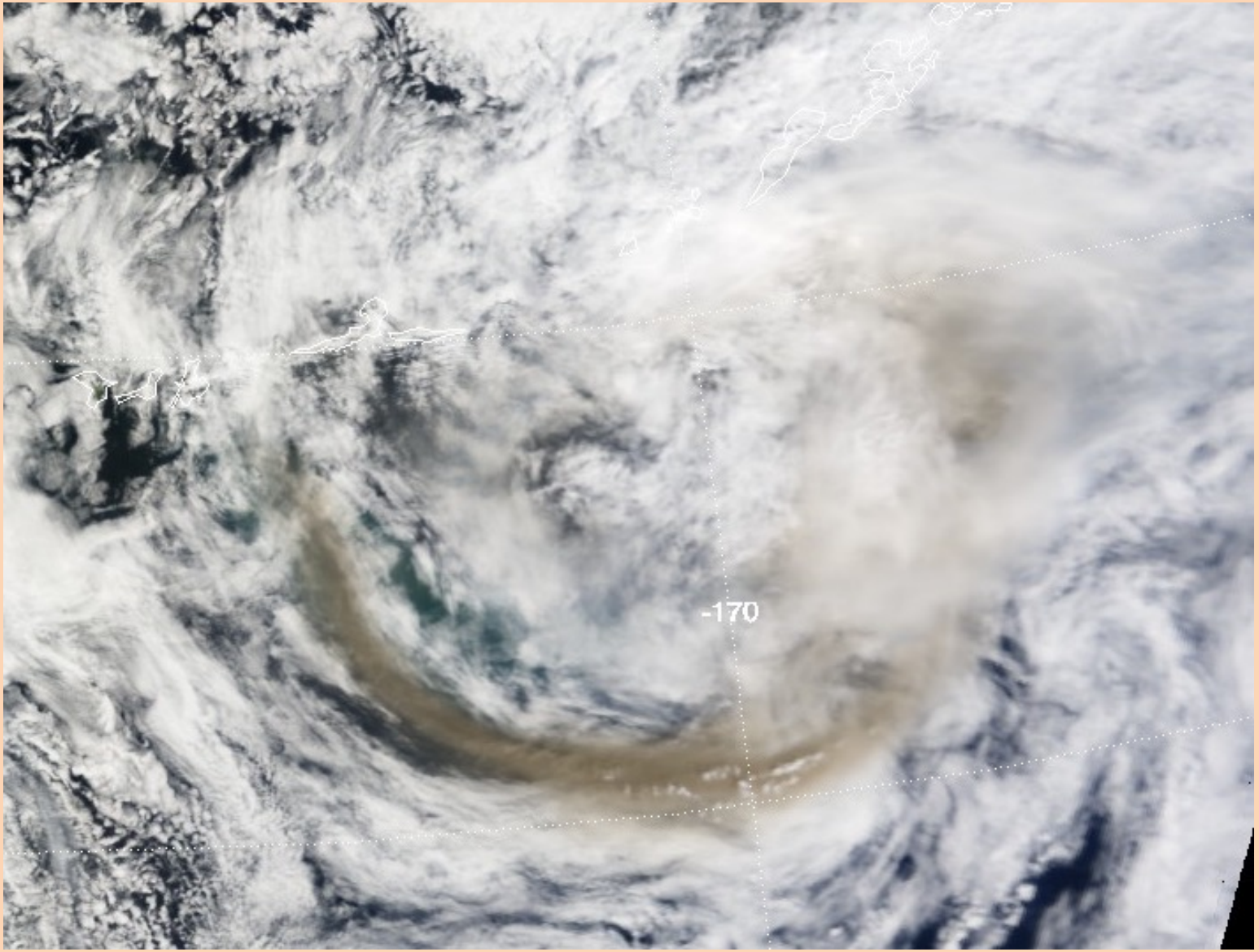
Panel response?

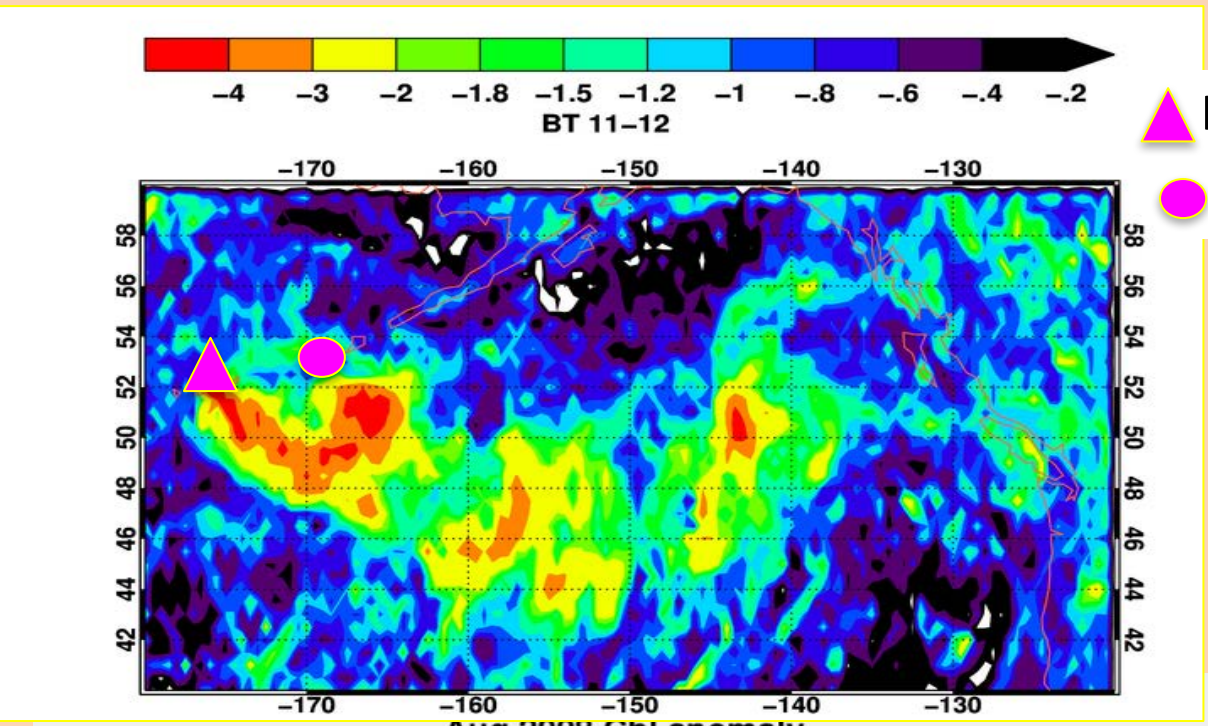
HA HA HA HA HA

"Many of these factors will make it difficult to test their deposition hypothesis. However, the importance of the issue of iron regulation of productivity over large areas of the world oceans makes this *high risk and high reward science*"

Getting our feet wet… with volcanic ash

Kasatochi eruption 7-8 August 2008

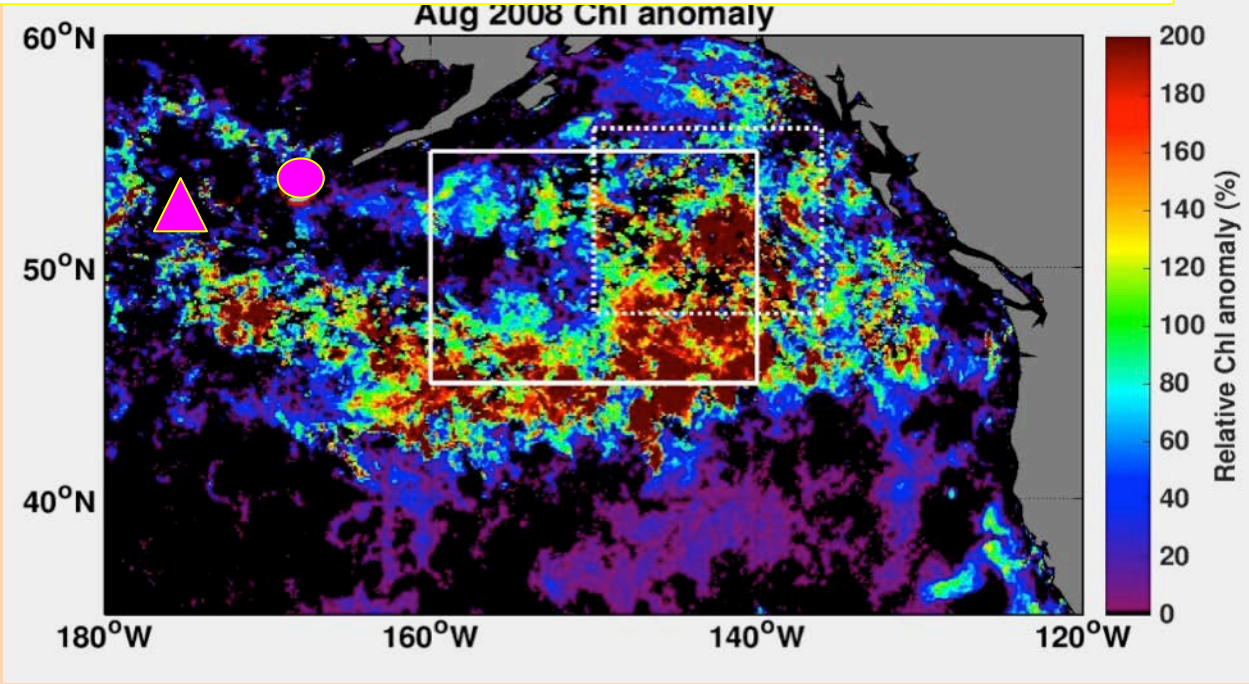




Kasatochi eruption 7-8 Aug 2008

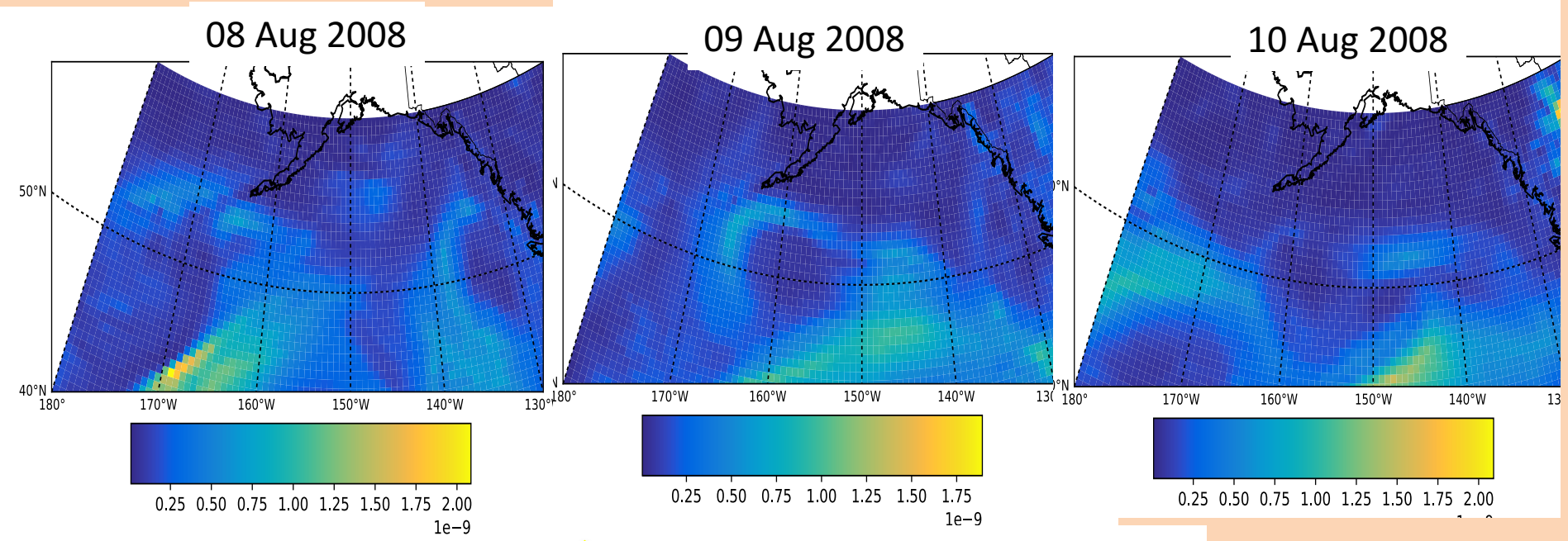
Okmok: 22 Jul to 18 Aug 2008

Atmosphere
Volcanic ash plumes
Composite BT 11-12
8-12 August 2008
(Yingxi Shi)



Ocean
Chl Aug 2008
anomaly

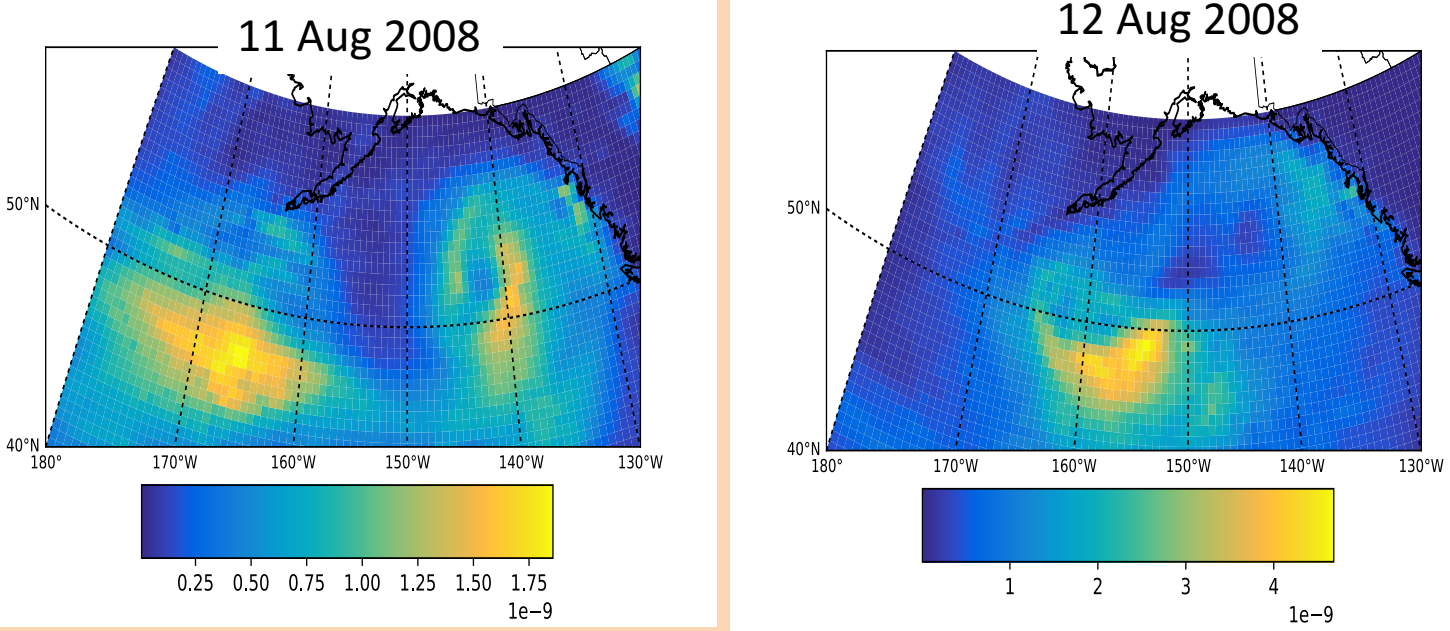
Monthly mean, but heavily influenced by latter half of the month.
(Toby Westberry)



Kasatochi eruption 7-8 Aug 2008

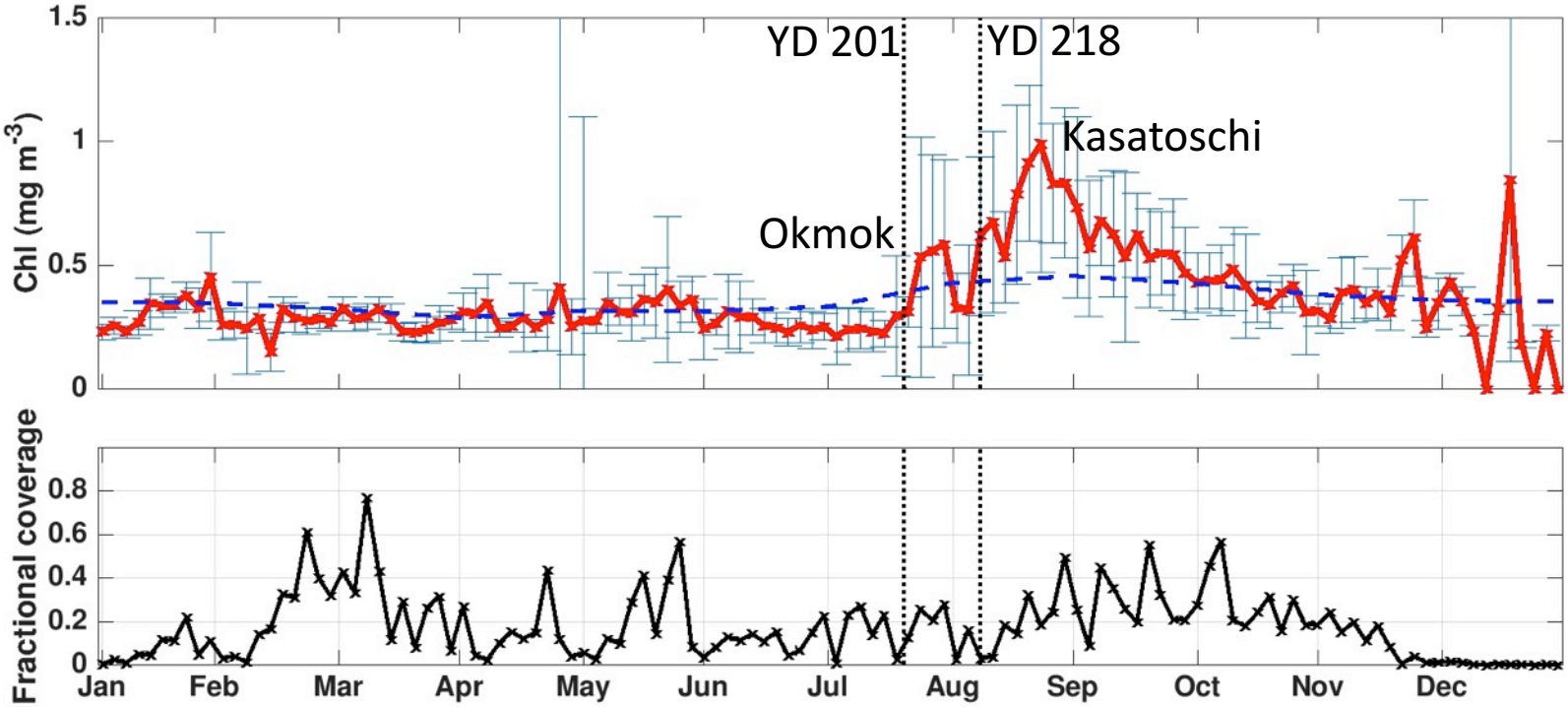
Okmok eruption 12 Aug 2008

MERRA-2
Total aerosol deposition



Volcanic Ash Example - Chlorophyll

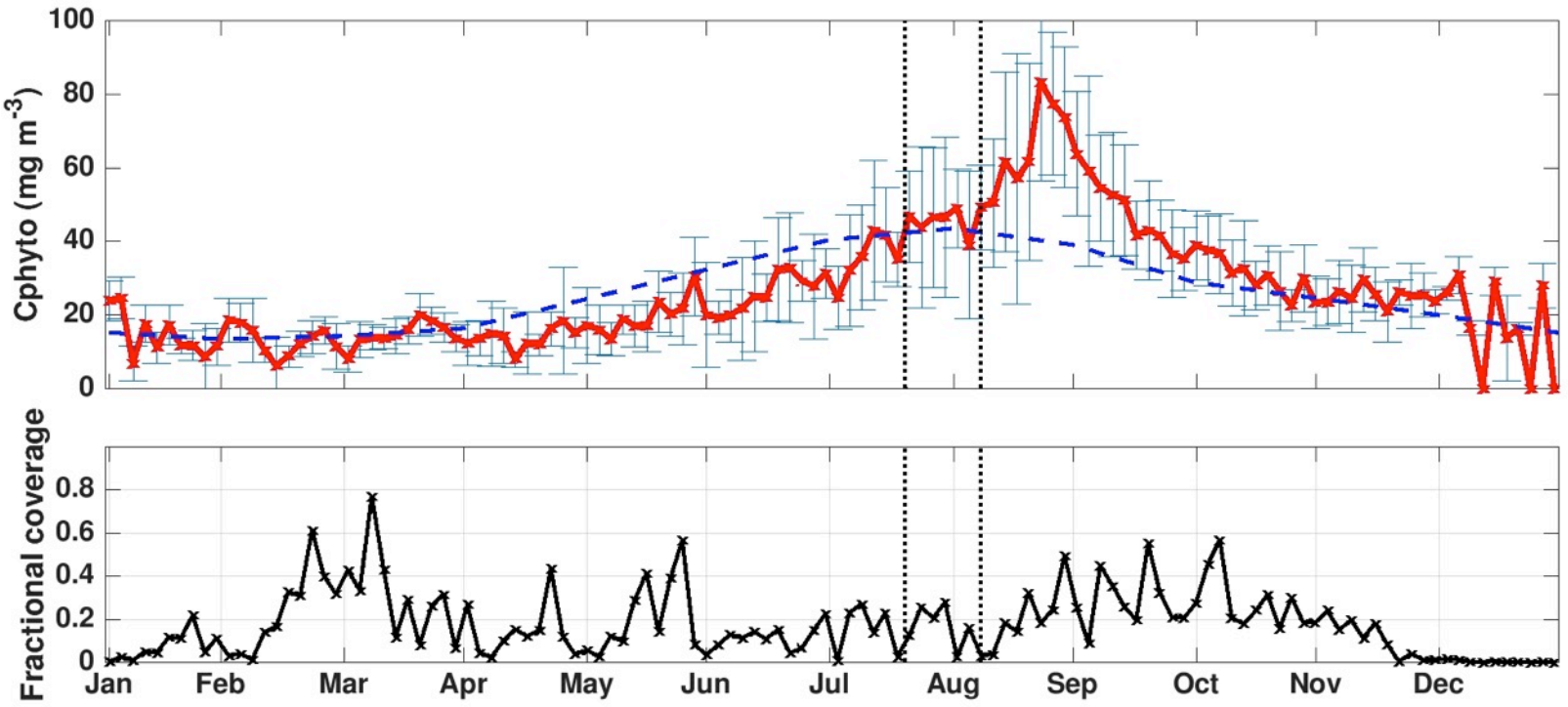
- 2008 time series of chlorophyll compared to climatology (blue dashed line)
- Vertical lines (black dotted) indicate first evidence of significant ash in atmosphere for Okmok and Kasatoschi
- Individual elevated chlorophyll signal after Okmok and Kasatoschi



Westberry et al., in prep

Volcanic Ash Example - biomass

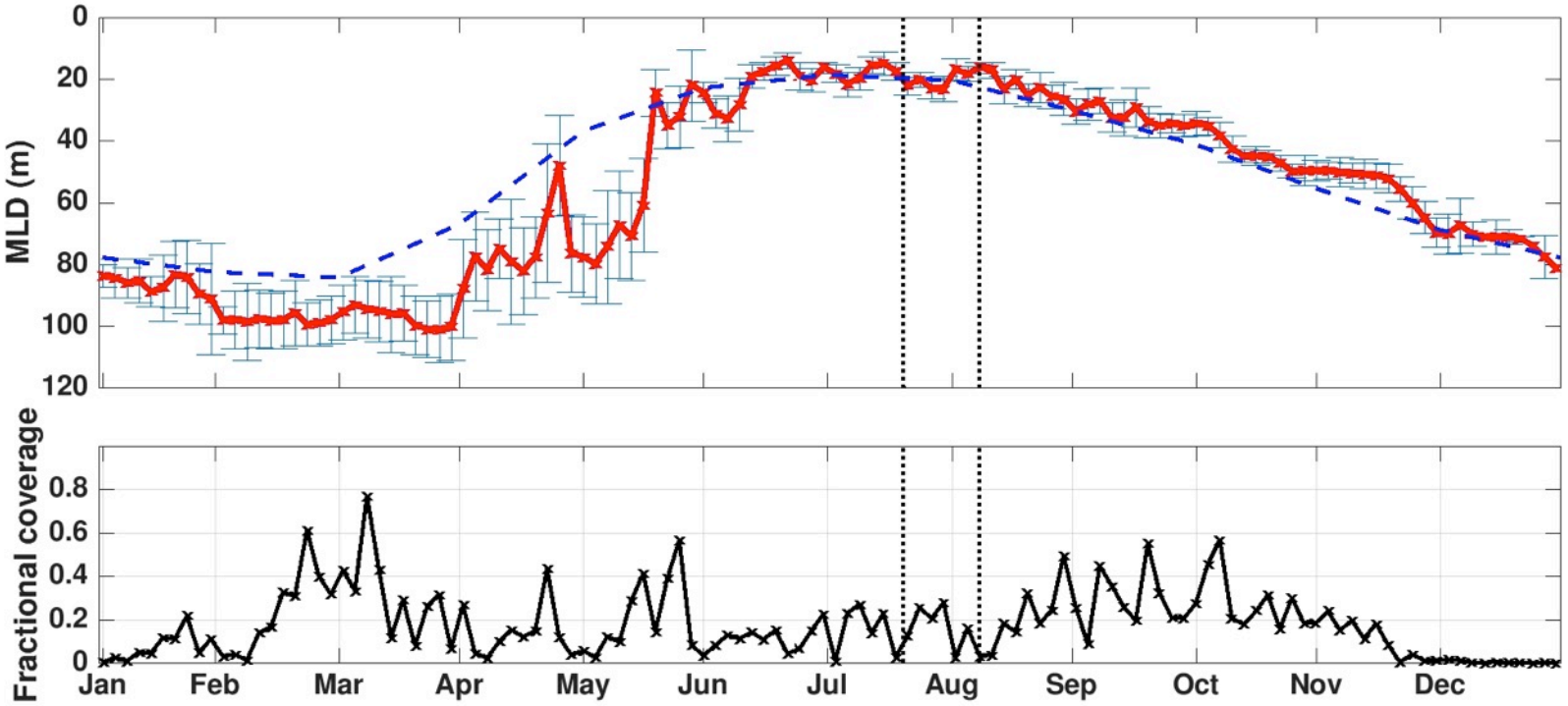
- 2008 time series of biomass compared to climatology (blue dashed line)
- Temporal evolution similar to Chl, but superimposed on a more significant seasonal cycle.
- Peak during 2008 occurs much later than typical seasonal maxima
- No signal for Okmak here, although increase in chlorophyll seen (previous slide).



Westberry et al., in prep

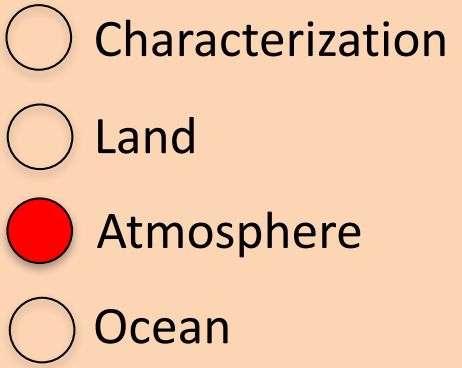
Volcanic Ash Example - physical

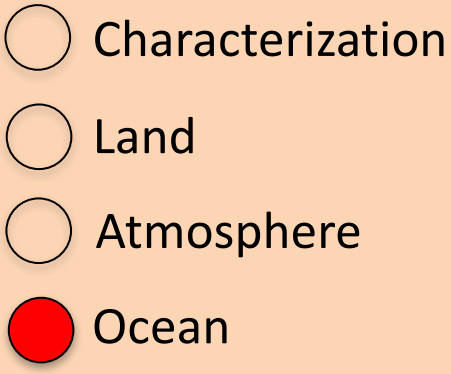
- 2008 time series of mixed layer depth compared to climatology (blue dashed line)
- Mixing seems typical for this time of year, suggesting physical controls on biomass and physiological acclimation are not anomalous



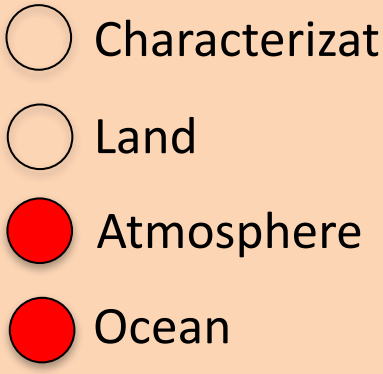
Entering Business Data into NSPIRES

- Characterization
- Land
- Atmosphere
- Ocean


Characterization
Land
Atmosphere
Ocean


Characterization
Land
Atmosphere
Ocean

Let’s give three cheers for interdisciplinary science!



Let’s give three cheers for interdisciplinary science!

- Characterization
- Land
- Atmosphere
- Ocean

Back up

1. Aerosol extinction/ backscatter profile from CALIOP or AOD from MODIS

Dust particles are large in size and non-spherical in shape

2. Dust extinction profile or Dust Optical Depth

Mass Conc. (g/m^3) = extinction/ MEE

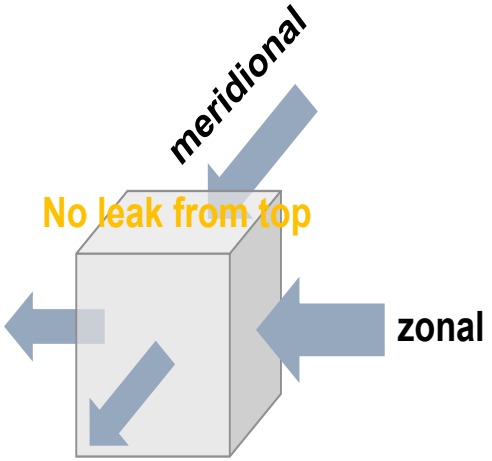
3. Profile or Column Dust Mass Concentration

MERRA Reanalysis wind

4. Dust Mass Flux

$F = \int m(z)u(z)dz$ or F=m*u

5. "Mass Balance" ➡ Dust deposition



Volcanic Ash Example - physiology

- 2008 time series of photoacclimation parameter compared to climatology (blue dashed line)
- Notable decreases following eruption/ash are not due to changes in mixing, but rather to decreased light availability (increasing Chl causes “self-shading”)